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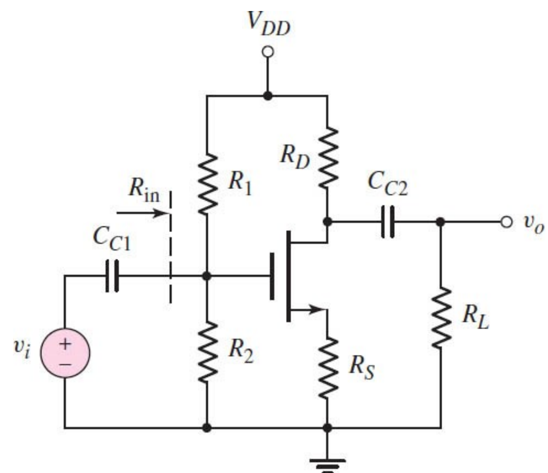
ECE322L - Homework 2 (100 points)
Assigned on Thursday, 02/06/2020-11 am
Due on Thursday, 02/13/2020-11 am

For the NMOS common-source amplifier in the figure below, the transistor parameters are: V_{TN} = 0.8V, K_n = 1mA/V², and λ = 0. The circuit parameters are V_{DD} = 5 V, R_S = 1kΩ, R_D = 4kΩ, R_1 = 225kΩ, and R_2 = 175kΩ. (a) Calculate the quiescent values I_{DQ} and V_{DSQ}. What is the operating region of the transistor? (b) Determine the small-signal voltage gain for R_L = ∞. (c) Determine the value of R_L that will reduce the small-signal voltage gain to 75 percent of the value found in part (b). Utilize the FET equations given in the Neamen to solve this problem.
Assume the frequency of the input signal is midrange, i.e., high enough for the coupling capacitors C_{C1} and C_{C2} to act as short circuits in ac but low enough for the gate capacitor to act as an open circuit in ac.



a) $I_{DQ} = K_n(V_{GS} - V_{tn})^2 = \frac{V_S}{R_S} = \frac{V_G - V_{GS}}{R_S} \quad \rightarrow \quad V_{GS} = V_G - R_S K_n (V_{GS} - V_{tn})^2$

$$V_G = \frac{R_2}{R_1 + R_2} V_{DD} = \frac{175k\Omega}{225k\Omega + 175k\Omega} 5V = 2.1875V$$

$$V_{GS} = V_G - R_S K_n (V_{GS} - V_{tn})^2 = 2.1875V - (1k\Omega)(1\frac{mA}{V^2})(V_{GS} - 0.8)^2 = 1.5796V$$

$$I_{DQ} = K_n\ (V_{GS} - V_{tn})^2 = 1\frac{mA}{V^2}(1.5796V - 0.8)^2 = 0.6079mA$$

$$V_{DSQ} = V_{DD} - I_D(R_D + R_S) = 5V - 0.6079mA(4k\Omega + 1k\Omega) = 1.9607V$$

$$V_{DS} \overset{?}{>} V_{GS} - V_{tn} \quad \rightarrow \quad 1.9607V > 1.5796V - 0.8V \quad \rightarrow \quad Saturation$$

b) $g_m = 2\sqrt{K_n I_D} = 2\sqrt{(1\frac{mA}{V^2})(0.6079mA)} = 1.5593\frac{mA}{V}$

$$A_{V_O} = -\frac{g_m R_D}{1 + g_m R_S} = -\frac{(1.5593\frac{mA}{V})(4k\Omega)}{1 + (1.5593\frac{mA}{V})(1k\Omega)} = -2.4371$$

c) $A_{V_{O_{new}}} = -\frac{g_m(R_D \parallel R_L)}{1 + g_m R_S} = -\frac{(1.5593\frac{mA}{V})(R_D \parallel R_L)}{1 + (1.5593\frac{mA}{V})(1k\Omega)} = (0.75)(-2.4371)$

$$= -0.60927(R_D \parallel R_L) = -1.8278$$

$$(R_D \parallel R_L) = 3k\Omega \quad \rightarrow \quad \frac{4k\Omega \times R_L}{4k\Omega + R_L} = 3k\Omega \quad \rightarrow \quad R_L = 12k\Omega$$